On the Index of Environmental Awareness

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Abstract

We develop a two-country model where each country contributes non-cooperatively to the global environment by improving its local environment. We introduce an index of environmental awareness, which measures how much a country is aware of the global environment. Then, we show that the index plays a key role in evaluating the effects of income growth and international transfers on the global environment.

Keywords: Environmental Awareness, Private Provision of Public Goods.

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1 Introduction

Disagreement over the control of the global environment was observed in the 1992 Rio de Janeiro and 1997 Kyoto Congresses. This conflict seems to imply that developed and developing countries differ about preference for the environment. To capture such difference, we develop an index of environmental awareness, which measures how much a country is aware of the global environment. Then, we show that several comparative statics results depend crucially on the environmental awareness of each country.

For the purpose of our analysis, we develop a two-country model with three features. First, the global environment is an international public good shared by the two countries.[1] Our model is an extension of models of private provision of public goods.[2] Second, each country obtains utility from its local environment as well as the global environment which depends on the quality of the local environment in each country. Third, each country's consumption has a negative effect on the local environment but it is counterbalanced by the positive effect of maintenance investment. These two effects spread over the global environment.

In this framework, we introduce an index of environmental awareness. This index is an extended version of Andreoni (1989, 1990) that evaluates the degree of impure altruism. By applying his analysis, we develop an index which measures how much a country is aware of the global environment.

The index we develop in this paper plays a key role in the comparative statics analysis. First, income growth of a country results in improvement in the global environment, and the effect becomes larger as the country is more aware of the global environment. Second, the effects of

[1] See, Buchholz and Konrad (1994), Niho (1996), Stranlund (1996), Murdoch and Sandler (1997), Ono (1998), and Caplan et al. (1999).

[2] See, for example, Warr (1983), Bergstrom et al. (1986), Buchholz and Konrad (1995), and Ihori (1996).

both conditional and unconditional aid programs on the global environment depend only on the relative degrees of environmental awareness between two countries. If the donor is more aware of the global environment than the recipient, then both types of aid programs result in the deterioration of the global environment.

The organization of this paper is as follows. Section 2 develops the model and shows the existence and uniqueness of equilibrium. Section 3 introduces the index of environmental awareness and shows its implication by considering the effects of income growth on the global environment. Section 4 evaluates the effects of international transfers on the global environment by using the index. Section 5 concludes.

2 The Model and Equilibrium

We consider a model with two countries, $i = 1, 2$. We assume that each country is represented by a benevolent government acting on behalf of its citizens.

Country i is endowed with w^i units of private goods. It divides income into consumption c^i and maintenance investment in the local environment, m^i. The budget equation of country i is:

$$c^i + m^i = w^i. \tag{1}$$

The local environment in country i, e^i, is improved by country i's maintenance investment but is worsened by its consumption. We express this mechanism as the formula:

$$e^i = -\beta^i c^i + \gamma^i m^i, \tag{2}$$

where $\beta^i > 0$ is a parameter which indicates the degree of consumption externality and $\gamma^i > 0$ is a parameter which shows the efficiency of maintenance investment.[3]

[3] Examples of maintenance investment are forestry programs, sewerage systems, development of electric cars, and so on. Examples of environmentally harmful activities are deforestation, water pollution, emissions from diesel trucks, and so on.

We assume that the quality of the global environment, E, is determined by:[4]

$$E = \sum_{i=1}^{2} e^i. \tag{3}$$

Country i obtains utility from consumption, the local environment, and the global environment. The utility of country i is $u^i(c^i, e^i, E)$ where $u^i : \Re^3_+ \to \Re$ is continuous, increasing, strictly quasi-concave, and twice continuously differentiable on $\Re^3_{++}$ with $\lim_{x \to 0} u^i_x = \infty$ ($x = c^i, e^i$, or E) where u^i_x means the partial derivative with respect to x.

We assume simultaneous and non-cooperative Nash behavior. Country i maximizes its utility subject to (1), (2), and (3) given the local environment of the other country $e^j (j \neq i)$. By substituting (1), (2), and (3) into the utility function, the maximization problem is equivalent to

$$\max_{\{E\}} u^i\left(\frac{1}{\beta^i + \gamma^i}(\gamma^i w^i + e^j) - \frac{1}{\beta^i + \gamma^i} E, E - e^j, E\right), \tag{4}$$

where $e^j (j \neq i)$ is given.

Differentiating (4) with respect to E and setting it equal to zero, we can determine the optimal level of E for country i :[5]

$$E = f^i\left(\frac{1}{\beta^i + \gamma^i}(\gamma^i w^i + e^j), e^j\right) \tag{5}$$

where $f^i : \Re^2_+ \to \Re_+$ is continuously differentiable on $\Re^2_{++}$. This is country i's demand function for the global environment. The first argument in f^i comes from the global environment dimension of the utility function, while the second argument comes from the local environment dimension of the utility function.

[4] We could consider that the quality of the global environment E is partially related to the local environment of each country in a complicated way. For example, traffic noise and water pollution only affect the local environment. On the other hand, air pollution can affect the global environment; and the total stock of greenhouse gases in the atmosphere is actually composed of emissions of those gases by each country. To make the analysis tractable, we express this complicated relationship between local and global environment in a simple manner expressed by (3).

[5] We have $m^i > 0$ from the boundary condition of the utility function.

By subtracting e^j from both sides of (5), we obtain a demand function of country i for its local environment:

$$e^i = f^i(\frac{1}{\beta^i + \gamma^i}(\gamma^i w^i + e^j), e^j) - e^j. \quad (6)$$

We can regard (6) as a Nash reaction function; country i chooses e^i given the other country's choice, $e^j (j \neq i)$. By using this reaction function, we show the existence of a unique non-cooperative Nash equilibrium. A *non-cooperative Nash equilibrium* is an allocation $\{\overline{c}^1, \overline{c}^2, \overline{m}^1, \overline{m}^2, \overline{e}^1, \overline{e}^2, \overline{E}\}$ such that (a) $\overline{e}^1$and $\overline{e}^2$ satisfies (6) for $i, j = 1, 2; i \neq j$; (b) $\overline{E} = \overline{e}^1 + \overline{e}^2$; and (c) $\{\overline{c}^i, \overline{m}^i, \overline{e}^i\}$ satisfies (1) and (2) for $i = 1, 2$. We obtain the following result:

Proposition 2.1: *There exists a unique and interior non-cooperative Nash equilibrium.*

Proof. See appendix. ■

3 The Index of Environmental Awareness: Definition and Implication

3.1 Definition

In this subsection, we introduce the index of environmental awareness which measures how much a country is aware of the global environment. To establish the index, we first consider the properties of the partial derivatives of f^i, $\partial f^i/\partial w^i$ and $\partial f^i/\partial e^j$ which evaluate how changes in income and other country's choices regarding local environment affect country i's demand for global environment, respectively. We then develop the index by using these derivatives.

Consider first the income effect: $\partial f^i/\partial w^i = \gamma^i f_1^i/(\beta^i + \gamma^i)$. If country i has no interest in the global environment, it would spend any additional unit of endowment only on consumption: $\partial f^i/\partial w^i = 0$. On the other hand, if country i is only concerned about the global environment, it would spend all additional endowment on environmental maintenance: $\partial f^i/\partial w^i = \gamma^i$. The value of the derivative increases as country i becomes more aware of the global environment.

Consider next $\partial f^i/\partial e^j = f_1^i/(\beta^i + \gamma^i) + f_2^i$. Suppose that the global environment is improved by one unit because of an increase in e^j by one unit. Then country i $(i \neq j)$ would respond by decreasing its maintenance investment and increasing its consumption, thereby decreasing e^i. In other words, the global environmental quality may increase less than one unit: $\partial f^i/\partial e^j \in (0, 1)$.

To show the above result, we first consider the case in which country i has no interest in the global environment: $u^i = u^i(c^i, e^i)$. In this case, the problem of country i is to maximize $u^i(c^i, e^i)$ subject to $c^i + m^i = w^i$ and $e^i = -\beta^i c^i + \gamma^i m^i$. Since e^j does not affect the choice of country i, we have $\partial f^i/\partial e^j = 1$. Thus, we have $\partial f^i/\partial e^j < 1$ in the case of $u^i(c^i, e^i, E)$.

To show that $0 < \partial f^i/\partial e^j$, we rewrite the utility maximization problem as:

$$\max_{\{c^i, e^i\}} u^i(c^i, e^i, e^i + e^j)$$
$$\text{s.t. } (1 + \frac{\beta^i}{\gamma^i})c^i + \frac{1}{\gamma^i}E = w^i + \frac{1}{\gamma^i}e^j \equiv \hat{w}.$$

The social wealth $\hat{w}$ increases as e^j increases. Since consumption, local environment, and global environment are normal goods with respect to social wealth, we have $0 < \partial f^i/\partial e^j$.

Suppose that country i is more aware of the global environment. Then, it reacts greatly to the improvement of the global environment made by country j $(j \neq i)$ so that it would respond by a larger decrease in its maintenance investment. On the other hand, if country i is less aware of the global environment, then it reacts little to the improvement. Therefore, $\partial f^i/\partial e^j$ becomes smaller as country i is more aware of the global environment.

Since a larger $\partial f^i/\partial w^i$ and a smaller $\partial f^i/\partial e^j$ imply greater awareness of the global environment for country i, it is natural to construct an index of environmental awareness by having $\partial f^i/\partial w^i$ in the numerator and $\partial f^i/\partial e^j$ in the denominator. Therefore, we define the index as follows:

Definition 3.1: *Country i's environmental awareness,* α^i $(i = 1, 2)$, is indexed by

$$\alpha^i \equiv \frac{\partial f^i / \partial w^i}{\partial f^i / \partial e^j} = \frac{f_1^i \frac{\gamma^i}{\beta^i + \gamma^i}}{f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i}. \tag{7}$$

Country i is more aware of the global environment as α^i becomes large.

The numerator of α^i shows the increase in the demand for the global environment when country i is faced with income growth. The greater value of the numerator implies that country i is more aware of the global environment. The denominator shows an increase in the demand for the global environment when the other country increases the quality of its local environment. A lower value of the denominator implies that country i is more aware of the global environment. Thus, a larger α^i means that country i is more aware of the global environment.

3.2 The Effect of Income Growth on the Global Environment

In this subsection, we demonstrate how much environmental awareness is important in analyzing the global environmental issues. In particular, we show that the effect of income growth on the global environment depends on the index of environmental awareness.

Differentiating the Nash reaction function of country i with respect to $\overline{e}^i$, $\overline{e}^j$, and w^i $(i \neq j)$, we have:

$$d\overline{e}^i = (f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i - 1) d\overline{e}^j + f_1^i \frac{\gamma^i}{\beta^i + \gamma^i} dw^i \tag{8}$$

Substituting $d\overline{e}^j = d\overline{E} - d\overline{e}^i$ and rearranging, we see that

$$d\overline{e}^i = \frac{f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i - 1}{f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i} d\overline{E} + \alpha^i dw^i. \tag{9}$$

Adding (9) for $i = 1$, $j = 2$ and (9) for $i = 2$, $j = 1$ and rearranging, we find that

$$d\overline{E} = c(\alpha^1 dw^1 + \alpha^2 dw^2), \tag{10}$$

where

$$c \equiv [1 + \sum_{i=1,2} \frac{1 - (f_1^i \frac{1}{\beta^i+\gamma^i} + f_2^i)}{f_1^i \frac{1}{\beta^i+\gamma^i} + f_2^i}]^{-1} > 0.$$

We thus obtain the following result:

Proposition 3.1: *Income growth of country i has a greater positive effect on the global environment than that of country j ($j \neq i$) if and only if country i is more aware of the global environment than country j.*

The coefficient c in (10) is the same regardless of which country is faced with income growth. Hence, (10) shows that whether the effect of country i's income growth on the global environment is greater than that of country j ($j \neq i$) depends on the relative degree of environmental awareness between the two countries. As regard to the effects of income growth on the local environment, we obtain the following results; income growth of country i has a positive effect on the local environment of country i and a negative effect on the local environment of country j ($j \neq i$).[6]

To understand this result, we first consider a situation where country 1 experiences income growth while country 2 does not. Country 1 can afford to invest more in its local environment because of the income effect. This implies improvement in country 1's local environment, and thereby improvement in the global environment.[7] However, an improvement of country 1's local environment leads to strategic interaction with country 2: country 2 chooses to lower the quality of its local environment thereby decreasing the quality of the global environment. In sum, the

[6] To show this result, we undertake comparative statics by using (8). Then, we obtain

$$\begin{aligned} \partial \overline{e}^i / \partial w^i &= \alpha^i f_1^i \frac{\gamma^i}{\beta^i + \gamma^i} / |D| > 0, \\ \partial \overline{e}^j / \partial w^i &= \alpha^i (f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i)(f_1^j \frac{1}{\beta^j + \gamma^j} + f_2^j - 1) / |D| < 0, \end{aligned}$$

where $|D| = 1 - \Pi_{j=1}^2 (f_1^j \frac{1}{\beta^j+\gamma^j} + f_2^j - 1) > 0$.

[7] For example, if a country spends much resources to reduce domestic gas emissions, then the total amount of emissions in the world would decrease.

effect is evaluated by $d\overline{E} = c\alpha^1 dw^1$. On the other hand, if country 2 is faced with income growth, then it contributes to an improvement in the global environment while country 1 does not. The total effect is evaluated by $d\overline{E} = c\alpha^2 dw^2$. Which case of income growth has a greater effect on the global environment depends on the relative degrees of environmental awareness between two countries.

4 International Transfers

In this section, we evaluate the effects of international transfers, i.e., conditional and unconditional aid programs on the global environment by using the index of environmental awareness.

4.1 Unconditional Aid

In this subsection, we consider unconditional aid. Without loss of generality, we assume that country 1 transfers a part of its income $\tau_l^1 \in (0, w^1)$ to country 2 in a lump-sum fashion. Since a marginal increase in lump-sum transfer implies $dw^1 = -d\tau_l^1$ and $dw^2 = d\tau_l^1$ in (10), we have

$$d\widetilde{E} = \widetilde{c}(\alpha^2 - \alpha^1) d\tau_l^1$$

where

$$\widetilde{c} \equiv [1 + \sum_{i=1,2} \frac{1 - (f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i)}{f_1^i \frac{1}{\beta^i + \gamma^i} + f_2^i}]^{-1} > 0.$$

We thus obtain the following result:

Proposition 4.1: *Unconditional aid has a positive effect on the global environment if and only if the recipient is more aware of the global environment relative to the donor.*

To interpret the results, suppose first that neither country obtains utility from the local environment. If country 1 implements a lump-sum transfer to country 2, then country 1 reduces its maintenance investment by the same amount, while country 2 invests all the transfer in its local environment. Thus, the global environment is unchanged as long as $\gamma^1 = \gamma^2$ (Warr (1983)). Suppose next that both countries obtain utility from their local environment. Such countries prefer a higher quality of the local environment. Hence, country 1 is unwilling to reduce its maintenance investment to offset a reduction in income, and country 2 is also unwilling to increase its maintenance investment following the increase in income. The relative degree to which both countries are unwilling to make these substitutions is reflected in the difference between the two indexes of environmental awareness, $\alpha^2 - \alpha^1$.

Official Development Assistance (ODA) to developing countries is often criticized in view of environmental preservation. This is because developing countries tend to spend most transfers on investment in infrastructure like buildings and dams, which are often harmful to the environment. However, our result shows that unconditional aid is harmful to the global environment, not because recipient (developing) countries do not use transfers for environmental maintenance, but because they are less aware of the global environment relative to donor countries. In order to make unconditional aid beneficial to the global environment, donor countries need to enlighten people in developing countries as to how much the preservation of the global environment is important.

4.2 Conditional Aid

In this subsection, we consider conditional aid: a donor requires that a recipient spends the transfer only on environmental maintenance. Without loss of generality, we assume that country 1 gives tied aid $\tau_m^2 > 0$ to country 2.

The budget equation of country 1 is $c^1 + m^1 = w^1 - \tau_m^2$ and the local environment in country 1 is $e^1 = -\beta^1 c^1 + \gamma^1 m^1$. For country 2, the budget equation is $c^2 + (m^2 + \tau_m^2) = w^2 + \tau_m^2$ and the local environment is $e^2 = -\beta^2 c^2 + \gamma^2 (m^2 + \tau_m^2)$. Substituting these constraints into the corresponding utility functions and solving the maximization problems, we can obtain Nash reaction functions for countries 1 and 2. The allocation under conditional aid, $\{\hat{e}^1, \hat{e}^2\}$, is characterized by the following Nash reaction functions:

$$\hat{e}^1 = f^1\left(\frac{1}{\beta^1+\gamma^1}(\gamma^1(w^1-\tau_m^2)+\hat{e}^2), \hat{e}^2\right) - \hat{e}^2, \tag{11}$$

$$\hat{e}^2 = f^2\left(\frac{1}{\beta^2+\gamma^2}(\gamma^2(w^2+\tau_m^2)+\hat{e}^1), \hat{e}^1\right) - \hat{e}^1. \tag{12}$$

By differentiating (11) - (12) with respect to $\hat{e}^1$, $\hat{e}^2$, τ_m^2 and rearranging, we obtain:

$$d\hat{E} = \hat{c}(\alpha^2 - \alpha^1)d\tau_m^2$$

where

$$\hat{c} \equiv [1 + \sum_{i=1,2} \frac{1-(f_1^i\frac{1}{\beta^i+\gamma^i}+f_2^i)}{f_1^i\frac{1}{\beta^i+\gamma^i}+f_2^i}]^{-1} > 0.$$

We obtain the following result:

Proposition 4.2: *Conditional aid has a positive effect on the global environment if and only if the recipient is more aware of the global environment relative to the donor.*

Many industrialized countries often implement conditional aid to developing countries. The aim of conditional aid is to make developing countries invest in the environment. Our result, however, indicates that conditional aid has the same implication for the global environment as unconditional aid. Whether conditional aid is beneficial to the global environment depends on the relative degrees of environmental awareness between the two countries.

5 Conclusion

In this paper, we introduce an index of environmental awareness, which measures how much a country is aware of the global environment relative to its local environment. Then, we show that environmental awareness plays a key role in evaluating the effects of income growth and international transfers on the global environment.

There have been many studies which analyze the effects of income growth and international transfers on the global environment in two- or many-country non-cooperative Nash equilibrium models. However, they have ignored the role of environmental awareness in evaluating the effects. Contrary to previous studies, we show that the effects of income growth and international transfers on the global environment depend critically on environmental awareness.

Appendix

We first show the existence of a Nash equilibrium. From (1) and (2), we have $m^i = \frac{1}{\beta^i+\gamma^i}(\beta^i w^i + e^i)$. By substituting (6) into the above equation and eliminating e^i, we obtain

$$m^i = \frac{1}{\beta^i + \gamma^i}\{\beta^i w^i - e^j + f^i\}. \tag{13}$$

Let $W = \{m \text{ in } \Re^2 : 0 \leq m^i \leq w^i \text{ for } i = 1, 2\}$. This is a compact and convex set. The function (13) is a continuous function from the set W to itself. Hence, by Brouwer's Fixed Point Theorem, there exists a fixed point, which is a Nash equilibrium vector m.

We next show the uniqueness of a Nash equilibrium. Suppose that E^* and E^{**} are two different equilibria of global environmental quality. We assume, without loss of generality, $E^* > E^{**}$. Since $E = e^1 + e^2$ and $e^i = -\beta^i c^i + \gamma^i m^i$, $i = 1, 2$, in equilibrium at E^*, at least for one country i, $e^{i*} > e^{i**}$ holds. This implies that country i invests more in the environment than in the equilibrium at E^{**}, i.e., $m^{i*} > m^{i**}$. Hence, from the budget constraint $c^i + m^i = w^i$, $c^{i*} < c^{i**}$ holds. However, from the normality assumption, the first-order condition of utility maximization problem $u^i_{c^i} = (\beta^i + \gamma^i)(u^i_{e^i} + u^i_E)$ is rewritten as $c^i = \phi^i(e^i, E)$ where $\partial\phi^i/\partial e^i > 0$ and $\partial\phi^i/\partial E > 0$. Then, $c^{i*} < c^{i**}$ and $e^{i*} > e^{i**}$ implies $E^* < E^{**}$ which is a contradiction. Therefore, the equilibrium of the global environmental quality is unique.

By combining (1) and (2), the reduced form of constraints in equilibrium is

$$\overline{c}^i + \frac{1}{\beta^i + \gamma^i}\overline{e}^i = \frac{\gamma^i w^i}{\beta^i + \gamma^i}. \tag{14}$$

Substituting $\overline{c}^i = \phi^i(\overline{e}^i, \overline{E})$ into the above, we have

$$\phi^i(\overline{e}^i, \overline{E}) + \frac{1}{\beta^i + \gamma^i}\overline{e}^i = \frac{\gamma^i w^i}{\beta^i + \gamma^i}. \tag{15}$$

Given $\overline{E}$, the left-hand side of (15) is strictly increasing in $\overline{e}^i$ so that (15) uniquely determines $\overline{e}^i$, and also (14) uniquely determines $\overline{c}^i$. Finally, $\overline{m}^i$ is uniquely determined by the budget constraint.

The solution is interior ($\overline{m}^i > 0$) from the boundary condition of the utility function.

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